Electromagnetic Insight of Professor Y. T. Lo and His Influence on My Research Career

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ABSTRACT

This paper, dedicated to the memory of Professor Y. T. Lo, describes two research projects that vividly remind me of his influence as well as my interactions with him which I cheerfully remember. These projects are the microstrip disk resonator and the meta-material research.

INTRODUCTION

It is my honor and privilege to be invited to, and to speak at, this memorial session for the late Professor Lo, who was my mentor throughout my professional career. He not only provided me with technical and professional advice but also demonstrated by his own example how we professionals must behave. In addition, I appreciated his willingness to talk about classical music and Chinese literature. Although his influence on me in the technical areas which helped me become what I am today cannot be singled out easily, I would like to share with you two of the technical subjects on which I significantly interacted with YT. On these topics, the spirit of YT is with me still. One of the topics is somewhat old and describes a technical oversight and failure of mine, while the other has an impact upon a more recent research theme.

MICROSTRIP DISK RESONATOR

During my post doc years, research on microstrip line structures was very popular. Following basic analysis of microstrip lines [1], my attention shifted to passive components. In the early 1970s, I undertook an analysis of microstrip disk resonators [2]. The analysis started with a quasi-static approach to calculate the total capacitance of the structure. Then, the radius of a hypothetical circular cylinder with a magnetic side wall filled with the substrate material with the same height as the substrate was obtained in such a way that the capacitance was equal to the value of the original capacitor. This 'effective' cylindrical resonator is then used for calculation of the resonant characteristics. Fig.1 illustrates the disk configuration and the effective structure described above.

As YT always emphasized the importance of experimental verification, I started measurement of a hand-made disk resonator. The result of the resonant frequency was reasonably accurate. However, I was surprised to find that the Q of the resonator was extremely small, much smaller than the Q estimated from the dielectric and metal losses. When my hand was extended over the disk, the return loss from the disk was significantly

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affected. Everyone now knows that I was actually conducting an experiment of a microstrip patch antenna. However, I completely missed this point and later learned a lesson that we should be flexible in thinking when undertaking a new project, especially an experimental one.

YT and his students later completed a very simple and yet useful analysis and design of microstrip patch antenna, of course including the radiation effect [3]. In the meantime, I was able to develop the Spectral Domain Immittance approach [4]. In the immittance approach as well as the spectral domain approach, two-dimensional Fourier spectra are analytically derived. With appropriate basis functions, two dimensional spectral integrations are carried out for the passive components such as a circular disk or a rectangular disk. If the wave number in the *x* direction is *?* and the one in the *y* direction is *?*, then the integration is over the entire *? -?* plain. Therefore, the integration always includes the radiation region (within the circle of radius *k*) and the surface wave poles. This is illustrated in Fig.2.

NEGATIVE REFRACTIVE INDEX STRUCTURES

Recently, my group has been involved in the studies of negative refractive index or left-handed materials and structures with emphasis on microwave applications. I was initially skeptical to the topic that was first highlighted by physicists [5]. The insertion loss was significant and dispersion was quite large. Because this is essentially an artificially synthesized 'material,' I recognized what Professor Lo mentioned to me [6] several times in the past in regard to artificial materials. The elements suspended in the mother materials should be as small as possible and should be random both in orientation and size if isotropy is desired. This would avoid resonance so that a broad band operation would be possible. In many microwave applications, planar structures are desired, typically made of printed transmission line components such as microstrip structures. To follow his suggestions, the approach we took was very different from the one in [5]. Eventually, we came up with a high-pass dual of the conventional microstrip transmission line. The unit element of the conventional and the LH line are illustrated in Fig.3. A practical implementation is shown in Fig.4. This unit element can be cascaded either in one dimension for an LH transmission line or in two dimensions for an LH surface [7]. Although this structure does not use resonant elements such as those in [5], the structure is still 'uniform.' In order to respond to YT's insight that artificial materials could sustain inclusions in a non-uniform manner, we have also recently developed a non-uniform LH structure [8]. It has been demonstrated that the characteristics of a section of such a non-uniform LH line can be tuned. For instance, a bandpass characteristic may be obtained by an appropriate non-uniformity.

CONCLUSIONS

This paper is dedicated to the late Professor Y. T. Lo. His influence on my research career is enormous and global. I have presented only two incidences in which YT provided an impact on my research. I would like to provide my deepest appreciations to YT who was really a Great Man who spent his life as a Traditional Chinese Scholar.

ACKNOWLEDGMENT

The author thanks the organizers of this session for providing me with this opportunity.

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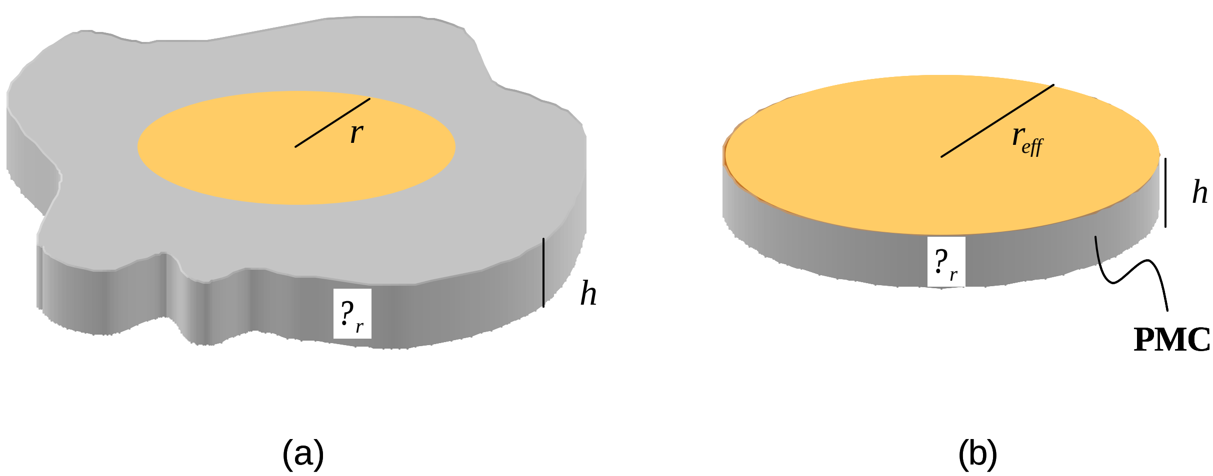


Figure 1 Microstrip disk and equivalent.

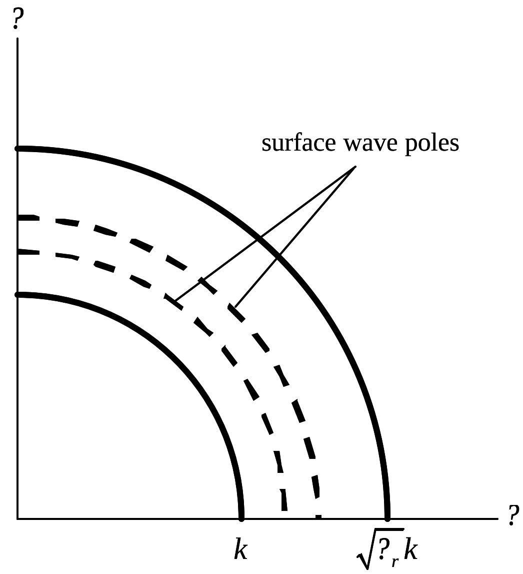
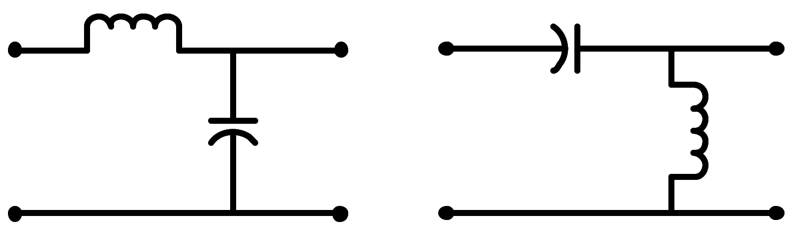


Figure 2 Spectral domain integration region. The ? and ? wave numbers are in the *x* and *y* direction, respectively.



(a) (b)

Figure 3 Unit element of RH (a) and LH (b) transmission line.

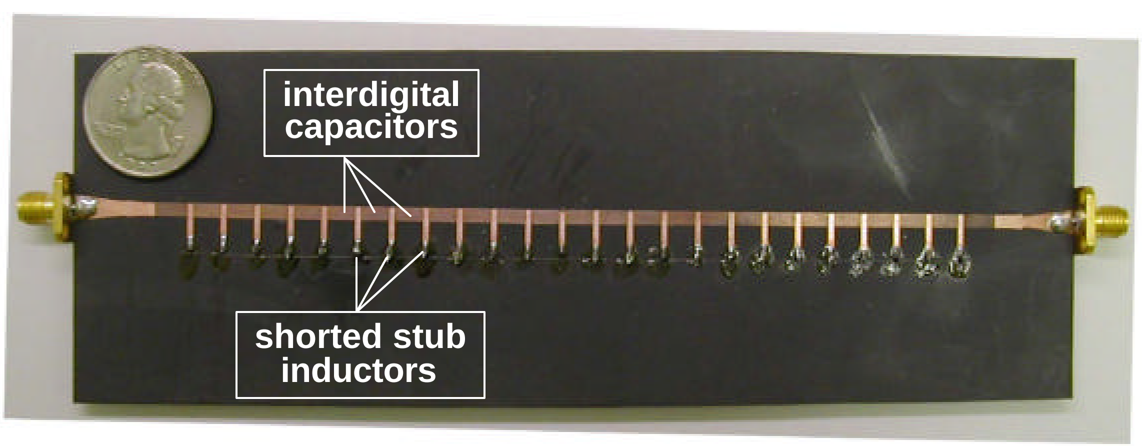


Figure 4 Photograph of a microstrip LH transmission line.